Assessing the Carcinogenic Risk of Mixtures using toxicity Equivalence Factors

Introduction

The toxicity equivalency factor (TEF) methodology was developed by the U.S. Environmental Protection Agency to estimate the hazard of a mixture of structurally related chemicals with a common mechanism of action. The TEF methodology is useful to estimate the hazards / risks of complex chemical mixtures where there is insufficient information to evaluate all of the chemicals that compose the mixture or the mixture itself. Generally, the TEF methodology is applied in situations where the chemical components of the mixture are known and the chemical composition of the mixture will not substantially change over time. This section of the CLARC Information System briefly describes the process for assessing the carcinogenic risk of mixtures using TEFs and provides the TEFs for mixtures of cPAHs and mixtures of CDDs and CDFs.

Assessing the Carcinogenic Risk of Mixtures of cPAHs

Polycyclic aromatic hydrocarbons (carcinogenic) or "cPAHs", as defined in WAC 173340-200, means those polycyclic aromatic hydrocarbons substances, PAHs, identified as A (known human) or B (probable human) carcinogens by the United States Environmental Protection Agency. These include benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.

When assessing the potential carcinogenic risk of mixtures of cPAHs under the MTCA Cleanup Regulation (WAC 173-340-708(8)(e)), one of the following two methods must be used unless the department determines that there is clear and convincing scientific data which demonstrates that the use of these methods is inappropriate: When using this methodology, each of the following compounds at a minimum must be analyzed for and included in the calculations:

(1) Assessment using Default Toxicity

The entire mixture is assumed to be as toxic as benzo(a)pyrene; OR

(2) Assessment using Toxicity Equivalence Factors

The toxic equivalency factors and methodology described in the following document is used:

CalEPA, 1994. "Benzo(a)pyrene as a toxic air contaminant. Part B: Health Assessment," Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Berkeley, CA.

When using this methodology, each of the following compounds at a minimum must be analyzed for and included in the calculations:

- Benzo[a]pyrene,
- Benz[a]anthracene,
- Benzo[b]fluoranthene,
- Benzo[k]fluoranthene,
- Chrysene,
- Dibenzo[a,h]anthracene, AND
- Indeno[1,2,3cd]pyrene.

The department may require additional compounds from the CalEPA list to be included in the methodology should site testing data or information from other comparable sites or waste types indicate the additional compounds are potentially present at the site.

NOTE: Many of the polycyclic aromatic hydrocarbons on the CalEPA list are found primarily in air emissions from combustion sources and may not be present in the soil or water at contaminated sites. Users should consult with the department for information on the need to test for these additional compounds.

Assessing the Carcinogenic Risk of Mixtures of CDDs and CDFs

Mixtures of chlorinated dibenzo-p-dioxin (CDDs) and chlorinated dibenzofurans (CDFs) are complex mixtures of 210 interrelated chemicals composed of different CDDs and CDFs. (U.S. EPA, 1989)
When assessing the potential carcinogenic risk of mixtures of CDDs and CDFs under the MTCA Cleanup Regulation (WAC 173-340-708(8)(d)), one of the following two methods must be used unless the department determines that there is clear and convincing scientific data which demonstrates that the use of these methods is inappropriate:

(1) Assessment using Default Toxicity

The entire mixture is assumed to be as toxic as 2, 3, 7, 8 TCDD: OR

(2) Assessment using Toxicity Equivalence Factors

The toxicity equivalency factors and methodology described in the following document is used:

U.S., EPA. 1989. *"Interim procedures for estimating risks associated with exposure to mixtures of chlorinated dibenzo-p-dioxins and dibenzofurans (CDDs and CDFs) and 1989 update,"* U.S. EPA, Risk Assessment Forum, Washington, D.C., EPA/625/ 3-89/016.

Determining Toxicity Equivalence Factors

A toxicity equivalency factor (TEF) is an estimate of the relative toxicity (by an order of magnitude) of a chemical compared to a **reference chemical**.

(1) Mixtures of cPAHs

For mixtures of cPAHs, the reference chemical is **benzo(a)pyrene**. Benzo(a)pyrene was chosen as the reference chemical because the toxicity of the chemical is well characterized. The toxicity equivalency factor for each cPAH is an estimate of the relative toxicity (by an order of magnitude) of the congener compared to benzo(a)pyrene.

Table 1: Toxicity Equivalence Factors for cPAHs

cPAH	Toxicity Equivalency Factor*
Benzo(a)pyrene**	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.1
Chrysene	0.01
Dibenzo(a,h)anthracene	0.4
Indeno(1,2,3-cd)pyrene	0.1

* Source: CalEPA, 1994. *"Benzo(a)pyrene as a toxic air contaminant. Part B: Health Assessment,"* Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Berkeley, CA.

** Reference chemical for cPAHs

(2) **Mixtures of CDDs and CDF**s

For mixtures of CDDs and CDFs, the reference chemical is 2,3,7,8 tetrachlorodibenzo-pdioxin (2,3,7,8 TCDD). 2,3,7,8 TCDD was chosen as the reference chemical because the toxicity of the chemical is well characterized. The toxicity equivalency factor for each CDD or CDF is an estimate of the relative toxicity (by an order of magnitude) of the congener compared to 2,3,7,8 TCDD.

Table 2: Toxicity Equivalence Factors for CDDs and CDFs

CDDs	Toxicity Equivalency Factor *	CDFs	Toxicity Equivalency Factor *
MonoCDDs	0.0	MonoCDFs	0.0
DiCDDs	0.0	DiCDFs	0.0
TriCDDs	0.0	TriCDFs	0.0
2,3,7,8-TCDD **	1.0	2,3,7,8-tetraCDF	0.1
Other tetraCDDs	0.0	Other tetraCDFs	0.0
1,2,3,7,8-pentaCDD	0.5	1,2,3,7,8-pentaCDF	0.05
Other pentaCDDs	0.0	2,3,4,7,8-pentaCDF	0.5
1,2,3,4,7,8-hexaCDD	0.1	Other pentaCDFs	0.0
1,2,3,6,7,8-hexaCDD	0.1	1,2,3,4,7,8-hexaCDFs	0.1
1,2,3,7,8,9-hexaCDD	0.1	1,2,3,6,7,8-hexaCDFs	0.1
Other hexaCDDs	0.0	2,3,4,6,7,8-hexaCDFs	0.1
1,2,3,4,6,7,8-heptaCDD	0.01	1,2,3,7,8,9-hexaCDFs	0.1
Other heptaCDDs	0.0	Other hexa CDFs	0.0
OctaCDD	0.001	1,2,3,4,6,7,8-heptaCDF	0.01
		1,2,3,4,7,8,9-heptaCDF	0.01
		Other heptaCDFs	0.0
		OctaCDF	0.001

* Source: U.S. EPA, 1989. *"Interim procedures for estimating risks associated with exposure to mixtures of chlorinated dibenzo-p-dioxins and dibenzofurans (CDDs and CDFs) and 1989 update,"* U.S. EPA, Risk Assessment Forum, Washington, D.C., EPA/625/ 3-89/016.

** Reference chemical for CDDs and CDFs

Determining Toxicity Equivalent Concentrations

To determine the toxicity equivalent concentration for mixtures of cPAHs, CDDs, and CDFs, the user should follow the following set of instructions:

1. Analyze the chemical mixture in a sample to determine the congeners and the concentration of each congener.

2. Multiply each congener concentration identified in the sample by the applicable toxicity equivalence factor (TEF) in the tables above to obtain a toxicity equivalent concentration (TEC).

3. Add the products in step 2 to obtain the total toxicity equivalent concentration (TTEC) for the chemical mixture.

4. Compare the total toxicity equivalent soil concentration (TTEC) for the chemical mixture with the applicable cleanup level for the reference chemical.

Example

Consider a site where the soil is contaminated with a mixture of cPAHs and assume that cleanup levels are established under Method B. The following steps should be followed to determine whether the soil concentrations exceed the cleanup level. Measured soil concentrations and calculations referred to in the following steps are presented in the table below.

Step 1: Analyze the cPAH mixture at the site to determine the congeners [column 1] and the soil concentration of each congener [column 2].

Step 2: For each congener identified at the site, multiply the soil concentration [column 2] by the applicable toxicity equivalence factor (TEF) [column 3] to obtain a toxicity equivalent soil concentration (TEC) [column 4].

Step 3: Add the products in step 2 to obtain the total toxicity equivalent soil concentration (TTEC) for the cPAH mixture [= 23.65 mg/kg].

Step 4: Compare the total toxicity equivalent soil concentration (TTEC) for the cPAH mixture [23.65 mg/kg] with the Method B cleanup level for benzo(a)pyrene [0.1 mg/kg].

The total toxicity equivalent soil concentration for the cPAH mixture [23.65 mg/kg] exceeds the Method B cleanup level for benzo(a)pyrene [0.1 mg/kg]. Therefore, the cleanup level for benzo(a)pyrene has not been met.

cPAH Congener	Measured Soil Concentration (mg/kg)	Toxicity Equivalence Factor (unitless)	Toxicity Equivalent Soil Concentration (mg/kg)
Benzo(a)pyrene	10	1.00	10.00
Benzo(a)anthracene	15	0.10	1.50
Benzo(b)fluoranthene	20	0.10	2.00
Benzo(k)fluoranthene	10	0.10	1.00
Chrysene	15	0.01	0.15
Dibenzo(a,h)anthracene	20	0.40	8.00
Indeno(1,2,3-cd)pyrene	10	0.10	1.00
Total	**100**		**23.65**